Mars Sample Return Architecture Development

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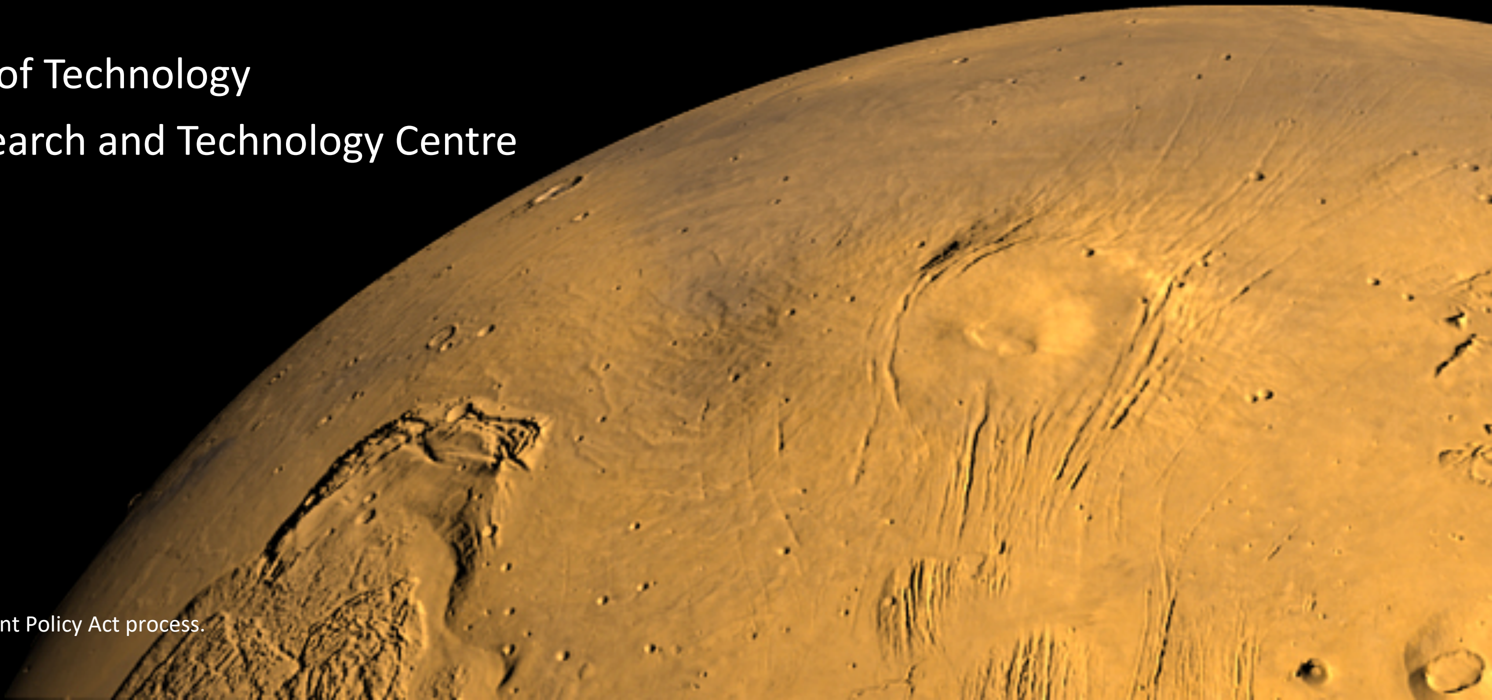
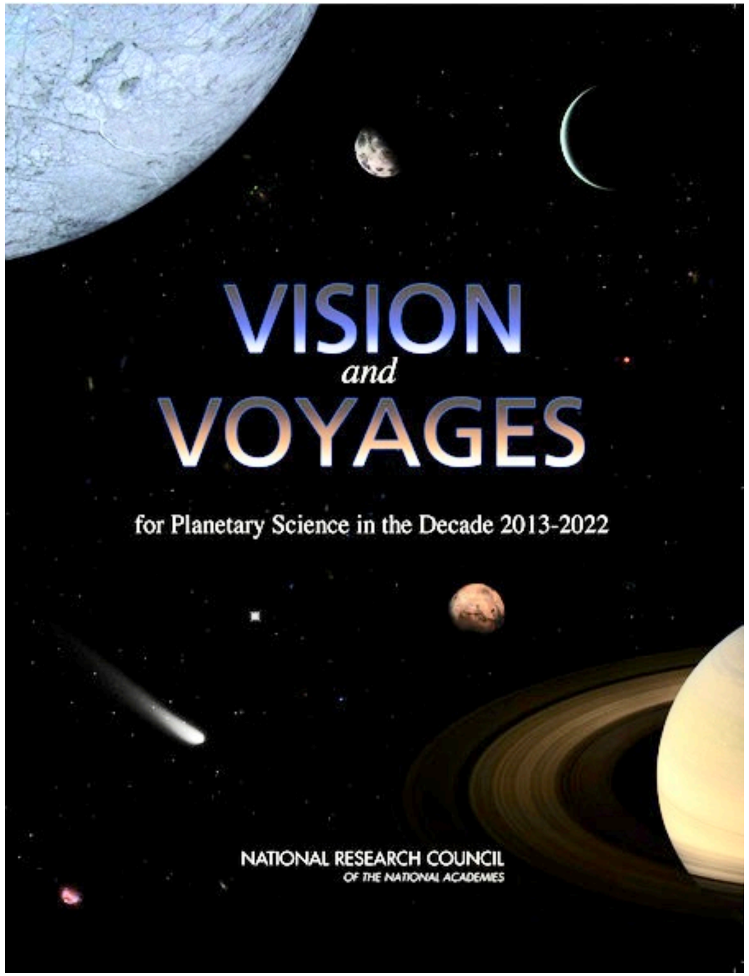


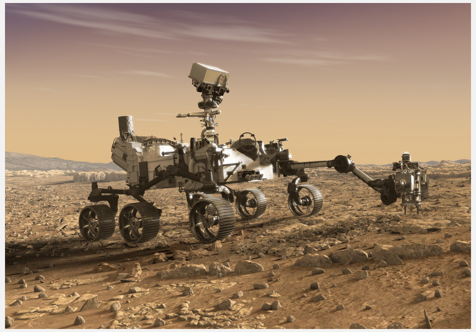
Mars Sample Return – a Decadal Survey Priority

- ***The NRC Planetary Science Decadal Survey (2011) provided a strong recommendation for MSR***
  - “**The major focus of the next decade will be to initiate a Mars sample-return campaign**, beginning with a rover mission to collect and cache samples, followed by missions to retrieve these samples and return them to Earth.”
  - “**A critical next step …. will be provided through the analysis of carefully selected samples** from geologically diverse and well-characterized sites that are returned to Earth for detailed study using a wide diversity of laboratory techniques”
  - “**The highest priority Flagship mission for the decade of 2013-2022 is MAX-C** (Mars astrobiology explorer-cacher)"
  - “During the decade of 2013-2022, **NASA should establish an aggressive, focused technology development and validation initiative** to provide the capabilities required to complete the challenging MSR campaign.”



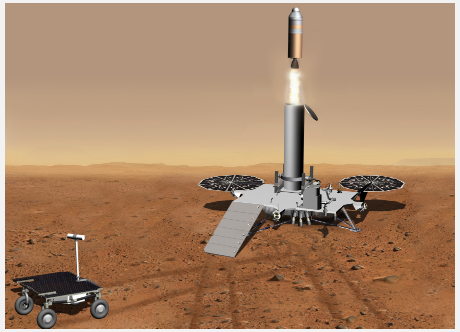
Notional Mars Sample Return Architecture (1/2)

- Three flight elements plus one ground element
  - Limits the cost, mass/volume, and technical challenges of each flight element



Sample Caching Rover (Mars 2020)

- *Sample acquisition and caching*

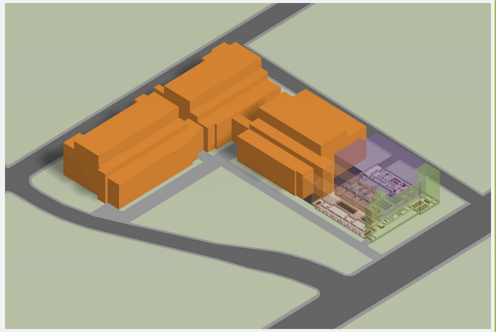


Sample Retrieval Lander*

- *Fetch Rover*
- *Orbiting Sample container (OS)*
- *Mars Ascent Vehicle*

Earth Return Orbiter*

- *Rendezvous and On-Orbit Capture System*
- *Earth Entry Vehicle*



Mars Returned Sample Handling*

- *Sample Receiving Facility*
- *Curation*
- *Sample science investigations*

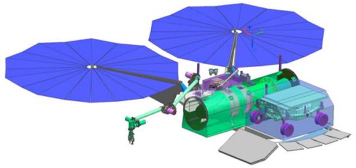
Flight Elements | ***Ground Element***

*Concepts

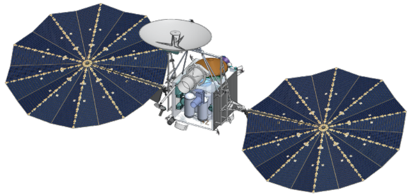
Notional Mars Sample Return Architecture (2/2)

Flight

Sample Caching Rover (Mars 2020)

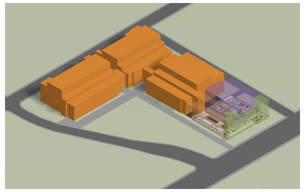


*Sample Retrieval Lander**



*Earth Return Orbiter**

Ground



*Mars Returned Sample Handling**

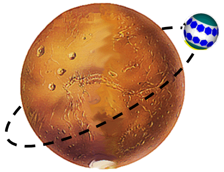
Launch from Earth/Land on Mars → Select Samples → Acquire/Cache Samples

→ Retrieve/Package Samples on Mars → Launch Samples to Mars Orbit *

→ Capture and Isolate Sample Container → Return to Earth → Land on Earth *

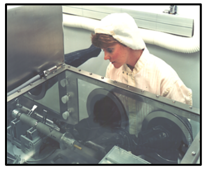
→ Retrieve/Quarantine and Preserve Samples on Earth → Assess Hazards → Sample Science

Sample Tube on Mars Surface⁺



Orbiting Sample (OS) in Mars Orbit⁺

Orbiting Sample (OS) on Earth⁺



Sample Science⁺

* Launching orders of MSR orbiter and lander can be reversed

*Concepts

⁺Artist's Concept

MSR Campaign – Decadal Survey Recommended Objectives

- **Acquire and return to Earth** a rigorously documented set of **Mars samples** for investigation in **terrestrial laboratories**
- Select samples based on their **geologic diversity**, **astrobiological relevance**, and **biosignature preservation** potential
- **Establish the field context** for each sample based on ***in situ* observations**
- Ensure the **scientific integrity** of the returned samples through **contamination control** (including round-trip Earth contamination and sample-to-sample cross-contamination) and **control of environments** experienced by the samples after acquisition
- **Ensure compliance with planetary protection requirements** associated with the return of Mars samples to the Earth biosphere

NASA-ESA Joint Statement of Intent

- *On April 26, 2018, in conjunction with the 2nd International MSR Conference in Berlin, GER, NASA and ESA signed a Joint Statement of Intent on Mars Sample Return*
- NASA:
  - Lead MSR Campaign system architecture
  - Lead Sample Retrieval Lander mission
  - Provide Sample Capture, Handling, and Containment System and Earth Entry Vehicle to ERO
- ESA:
  - Lead Earth Return Orbiter mission
  - Provide Sample Fetch Rover and Sample Transfer Arm to SRL
- *Joint plan to be developed for NASA/ESA approval by the end of CY 2019*

Joint Statement of Intent between the National Aeronautics and Space Administration and the European Space Agency on Mars Sample Return

April 26, 2018

Pursuant to the highest objectives established by the international scientific community for planetary science, the National Aeronautics and Space Administration (NASA), and the European Space Agency (ESA), expressed a mutual interest in pursuing cooperation on Mars sample return activities through the signature of a 2008 Agreement addressing potential cooperation on future space exploration sample return activities that extends through December 31, 2020;

Recognizing that NASA and ESA continue sharing the common objective of together preparing and launching a set of complementary missions by the end of the next decade that would return samples from Mars to Earth for scientific research;

Recognizing that both agencies are implementing missions and conducting preparatory activities which will contribute to the realisation of a Martian sample return mission, including the NASA Mars 2020 mission that will cache samples for return to Earth and the ESA-Roscosmos Trace Gas Orbiter and ExoMars missions that will expand ESA's operational experience at Mars;

Recognizing that the 2016 ESA Council meeting at the Ministerial level mandated that ESA prepare for the next ESA Mars mission, considering European participation in an international Mars Sample Return (MSR) mission as a key objective;

Recognizing that the United States Fiscal Year 2019 President's Budget Request directs NASA to plan a potential MSR mission leveraging international and commercial partnerships; and

Recognizing NASA and ESA's mutual objective to collaborate on a joint MSR endeavor potentially based on a reference architecture under consideration whereby NASA would lead a MSR campaign as the systems architect and lead an MSR Lander (SRL) mission, and ESA would lead a MSR Orbiter mission and provide the Sample Fetch Rover and the Sample Transfer Arm to the SRL mission and NASA would provide the Sample Capture, Handling, and Containment system and the Earth Entry Vehicle to the MSR Orbiter; this endeavor may be in concert with other international or commercial partners;

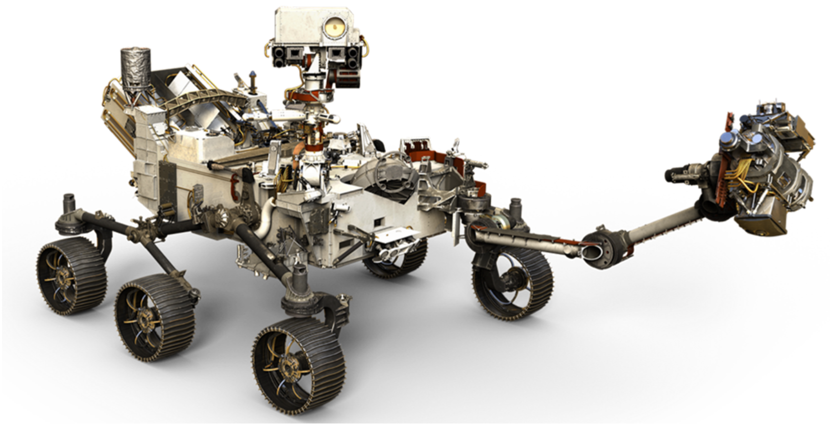
NASA and ESA intend to develop a joint MSR plan and to complete the studies needed to reach the level of technical and programmatic maturity required to pursue an effective MSR partnership, specifically defining the respective roles and responsibilities sufficient to lead to an international agreement between the two agencies in time to be submitted for approval to their respective authorities at the end of 2019.

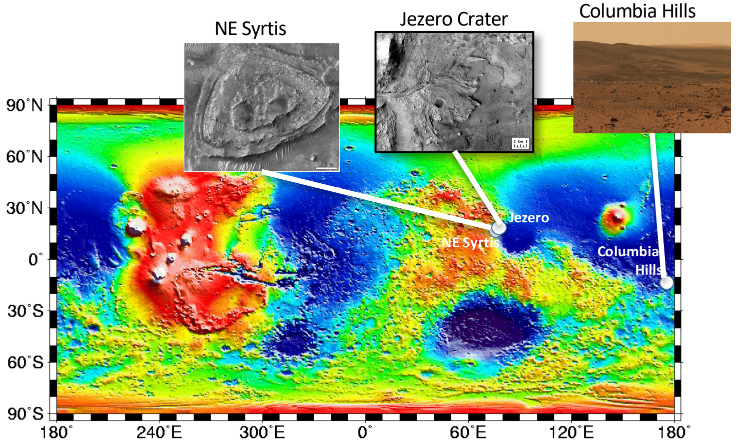
Thomas Zurbuchen
Associate Administrator
for Science
NASA

David Parker
Director
Human and Robotic Exploration
Programmes
ESA

Mars 2020

- High heritage from MSL
- EDL improvements
  - Range trigger for parachute deployment
  - Terrain-Relative Navigation for accessing more hazardous (& more scientifically interesting) sites
  - 11x9 km landing ellipse
- Three landing site finalists selected
  - Jezero Crater
  - NE Syrtis
  - Columbia Hills
- Adaptive caching strategy
  - Also evaluating option to deliver tubes to SRL
- Sample tube design
  - Length: 144.3 mm
  - Mass: ~80 g (empty); ~100-120 g (w/ 10 cc sample)





M2020 Landing site candidates

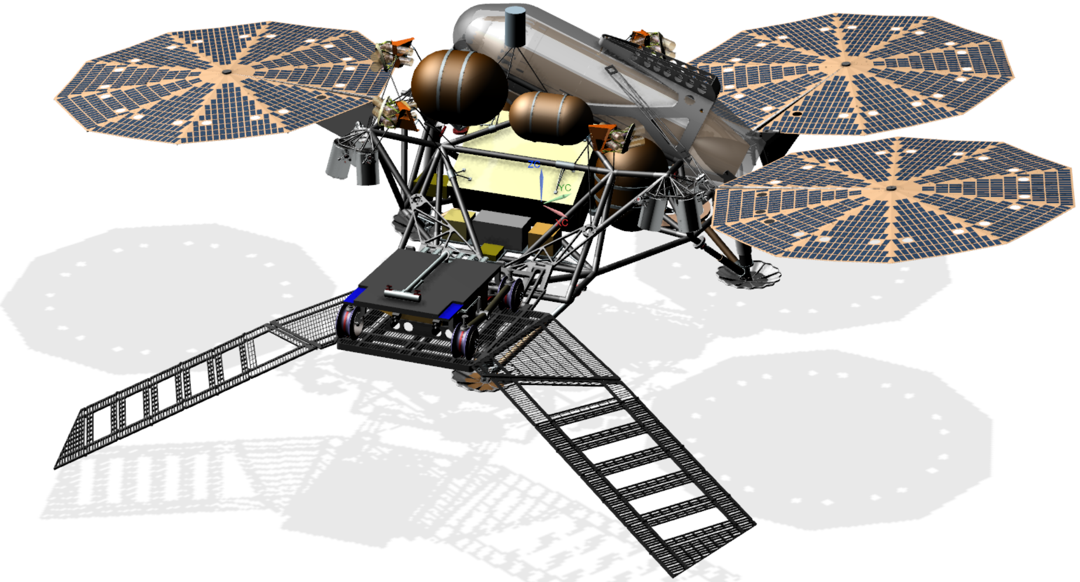
Site	ID	Latitude	Altitude
Jezero	JEZ	18.4 N	-2.64 km
NE Syrtis	NES	17.9 N	-2.04 km
Columbia Hills	CLH	14.5 S	-1.93 km


M2020 Returned Sample Tube Assembly

Notional Sample Retrieval Lander

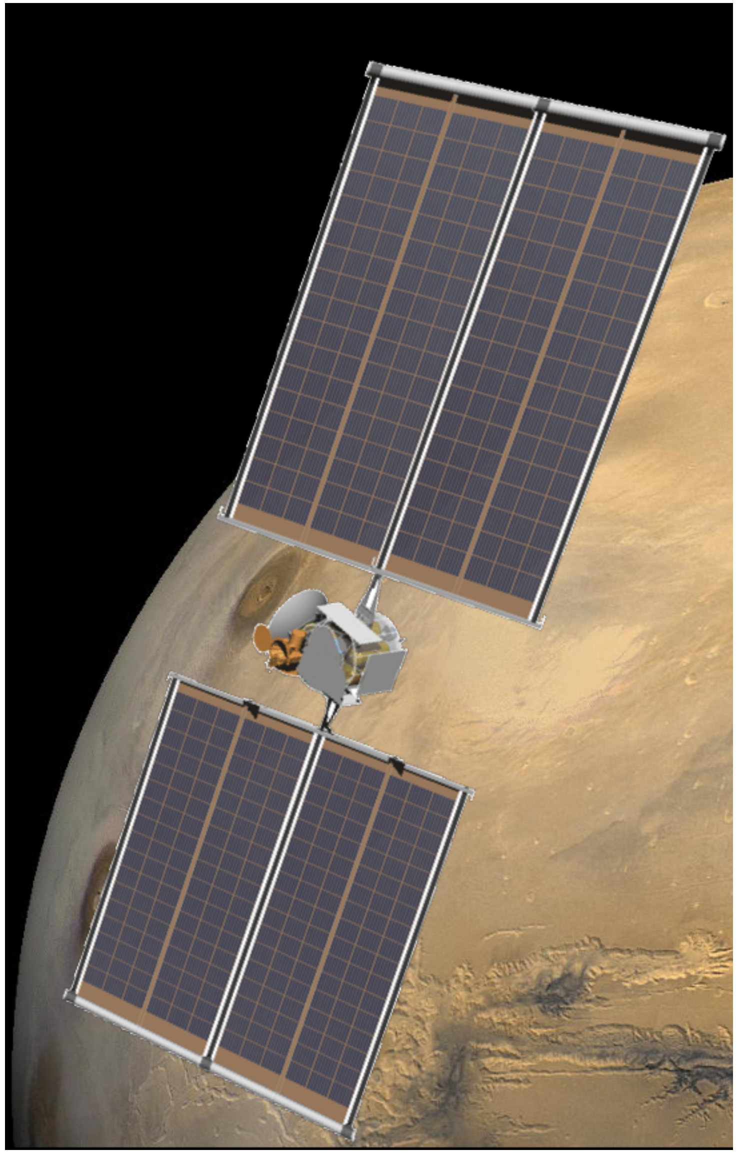
Artist's Concept

- Key Functions:
  - Deliver Fetch Rover and MAV to appropriate landing site to achieve sample tube pick up and transfer to the OS
  - Launch MAV into low Mars orbit (~320 km orbit, ~20 deg inclination)
- Payload
  - MAV + Fetch Rover (~500 kg)
- Flight system
  - Pallet Lander deployed by MSL/M2020-heritage Skycrane or Propulsive Platform Lander (Phoenix/InSight/Viking heritage)
  - Solar powered (~16 m2 active area)



Notional Earth Return Orbiter

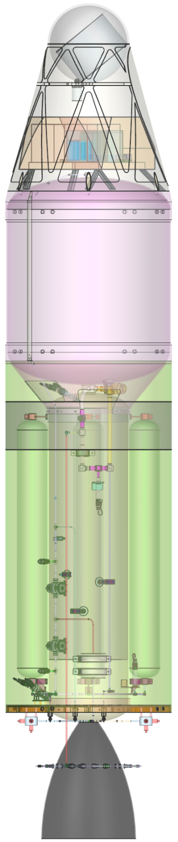
Artist's Concept



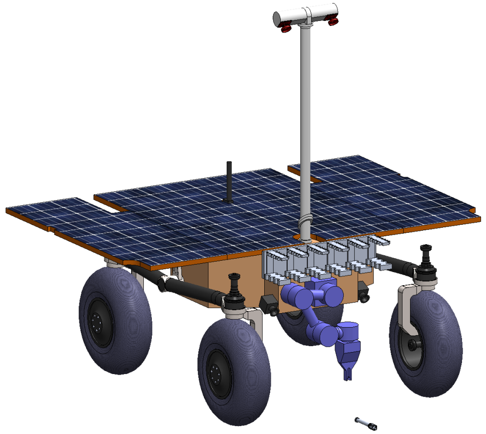
- Key functions
  - Communication telemetry and tracking during MAV launch
  - Rendezvous & Capture of on-orbit OS
  - Containment and Earth Planetary Protection
  - Return to Earth
    - Release of Earth Entry Vehicle on direct entry trajectory
    - Delivery of contained samples to cis-lunar space for human-assisted return
- Payload
  - Capture/Containment and Return System (CCRS)
- Flight System
  - Currently assessing Chemical and Electric Propulsion options for this high-ΔV mission
  - Staging (jettison of orbiter elements prior to Earth return) likely required
- Status: ESA has initiated Phase A/B1 contracts with Airbus and TAS-I to develop ERO mission concepts

Key MSR Technology and Advanced Engineering Needs

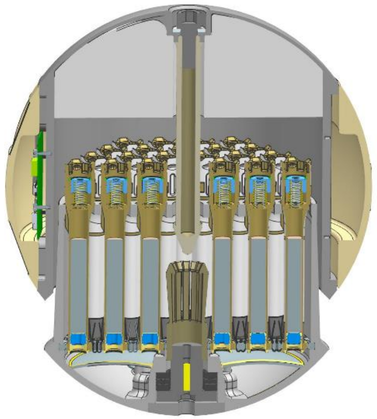
Sample Retrieval Lander*



Mars Ascent
Vehicle

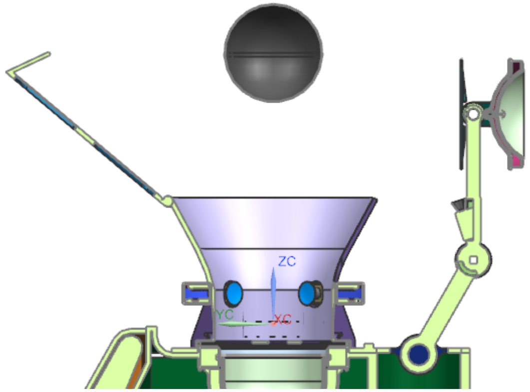


Sample
Fetch Rover

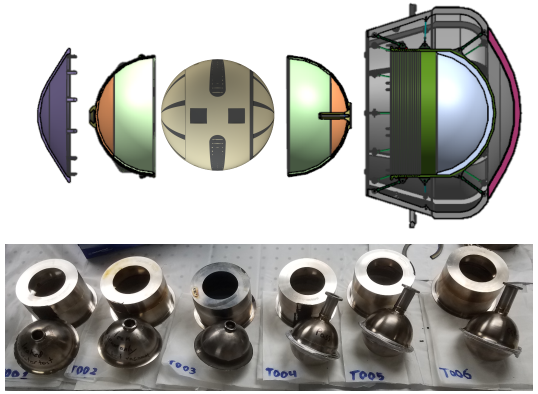


Orbiting Sample (OS)
Container

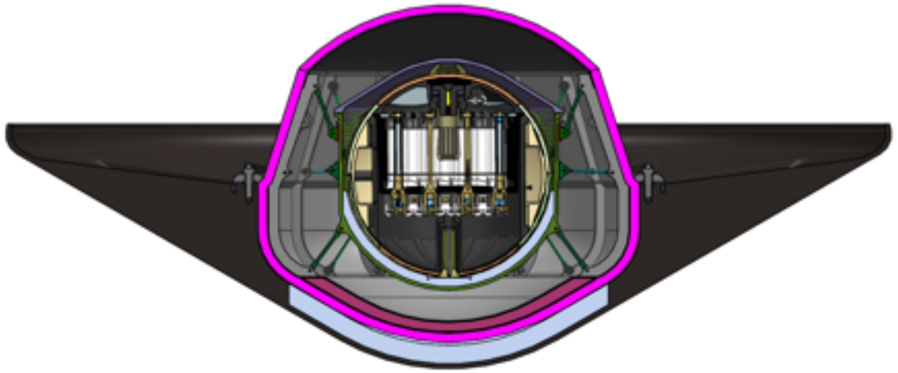
Earth Return Orbiter*



Rendezvous and
Capture



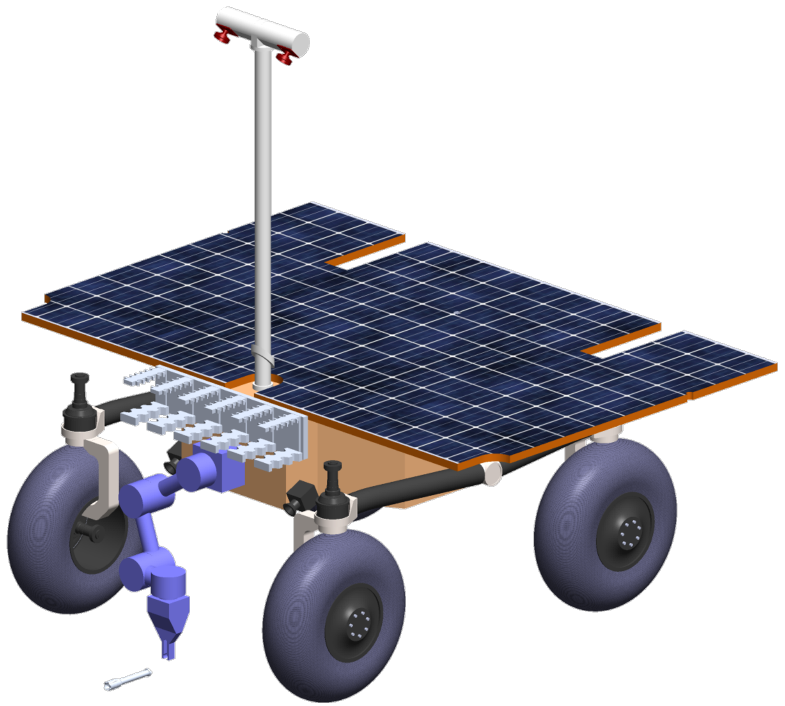
Containment Assurance



Earth Entry Vehicle

Sample Fetch Rover Concept

- Key functional requirements
  - Able to drive out SRL landing dispersion
  - Compatible with M2020 candidate sites
    - Jezero Crater
    - NE Syrtis
    - Columbia Hills
  - ~30 km drive (wheel odometry)
  - ~200-sol surface fetch mission
  - Capable of retrieving up to 31 sample tubes
  - 120 kg mass (NTE)
  - UHF relay telecommunications
- Status: ESA and CSA are independently studying SFR concepts with industry

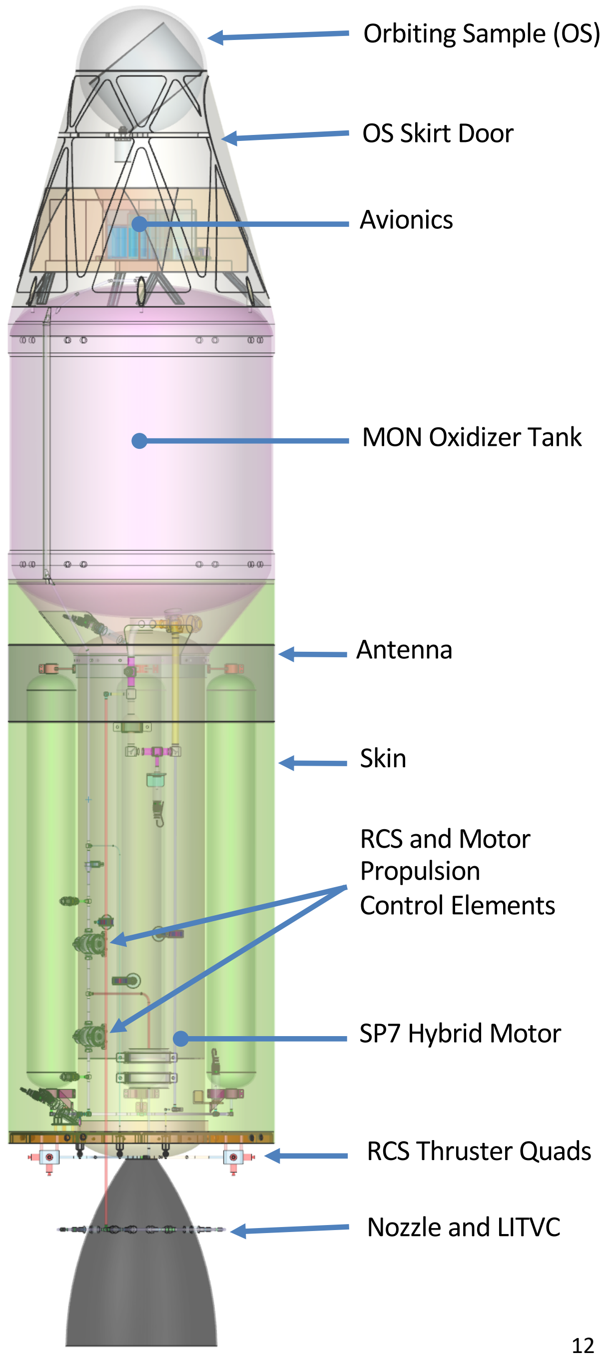


Notional NASA SFR Concept

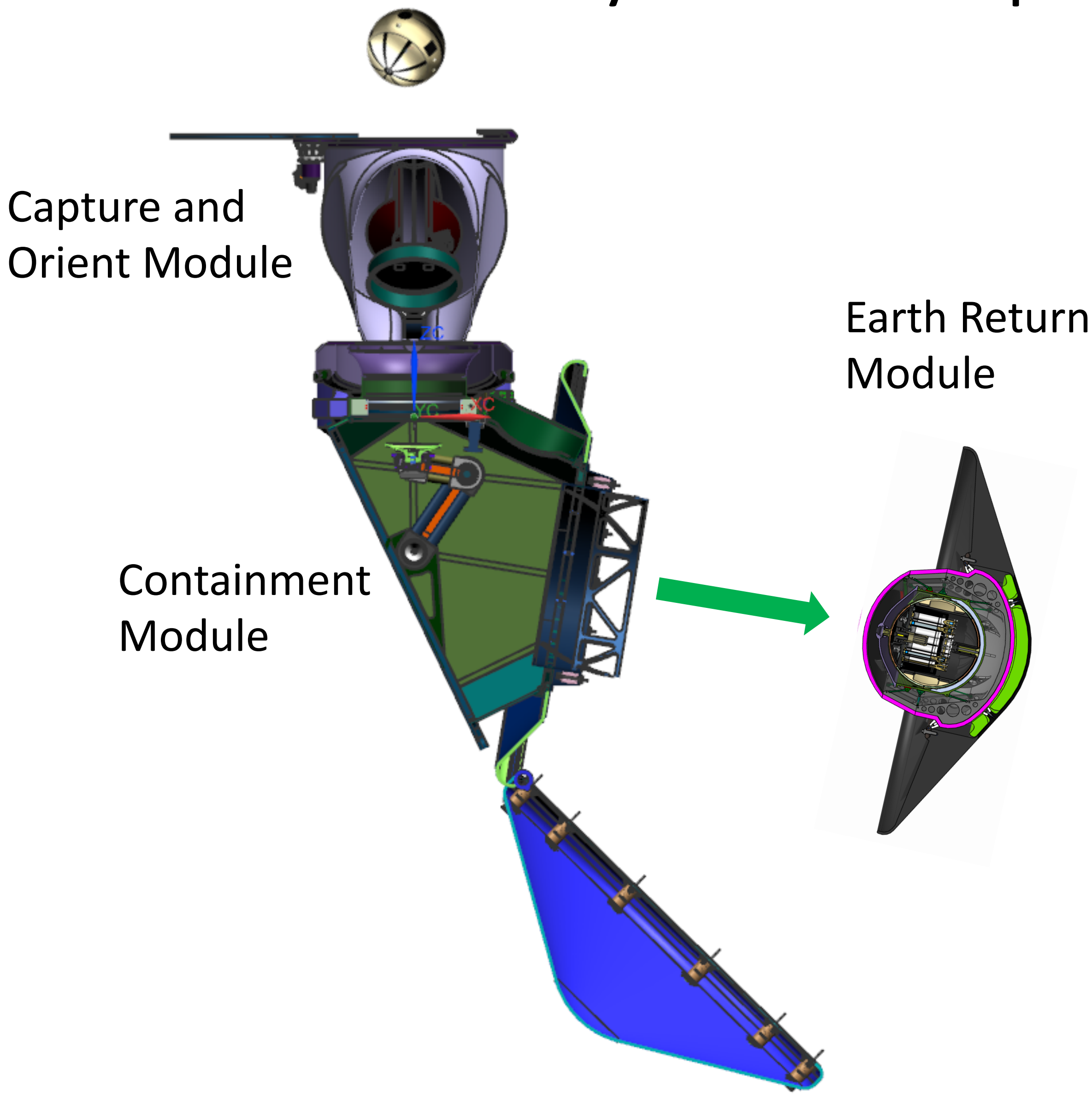
MAV Reference Design

- Hybrid propulsion option selected based on MAV trade study (JPL/MSFC/LaRC)
  - Single-Stage-To-Orbit Design
    - Target Orbit 320 km @ 20o Inclination
    - 12 kg OS Capability (31-Tubes)
  - Length: 2.4 m x Diameter: 0.57 m
  - GLOM Range: 290-305 kg (w/ 50% margin)
    - Varies with launch uncertainties
  - Mass Fractions
    - Propulsion Dry Mass : 10%
    - Non-propulsion Dry Mass : 12%
    - Oxidizer Mass: 63%
    - Fuel Core Mass: 14%
    - Helium Mass: <1%

GLOM	Gross Liftoff Mass
LITVC	Liquid Injection Thrust Vector Control
OS	Orbiting Sample
RCS	Reaction Control System
TPS	Thermal Protection System



Capture/Containment and Return System Concept

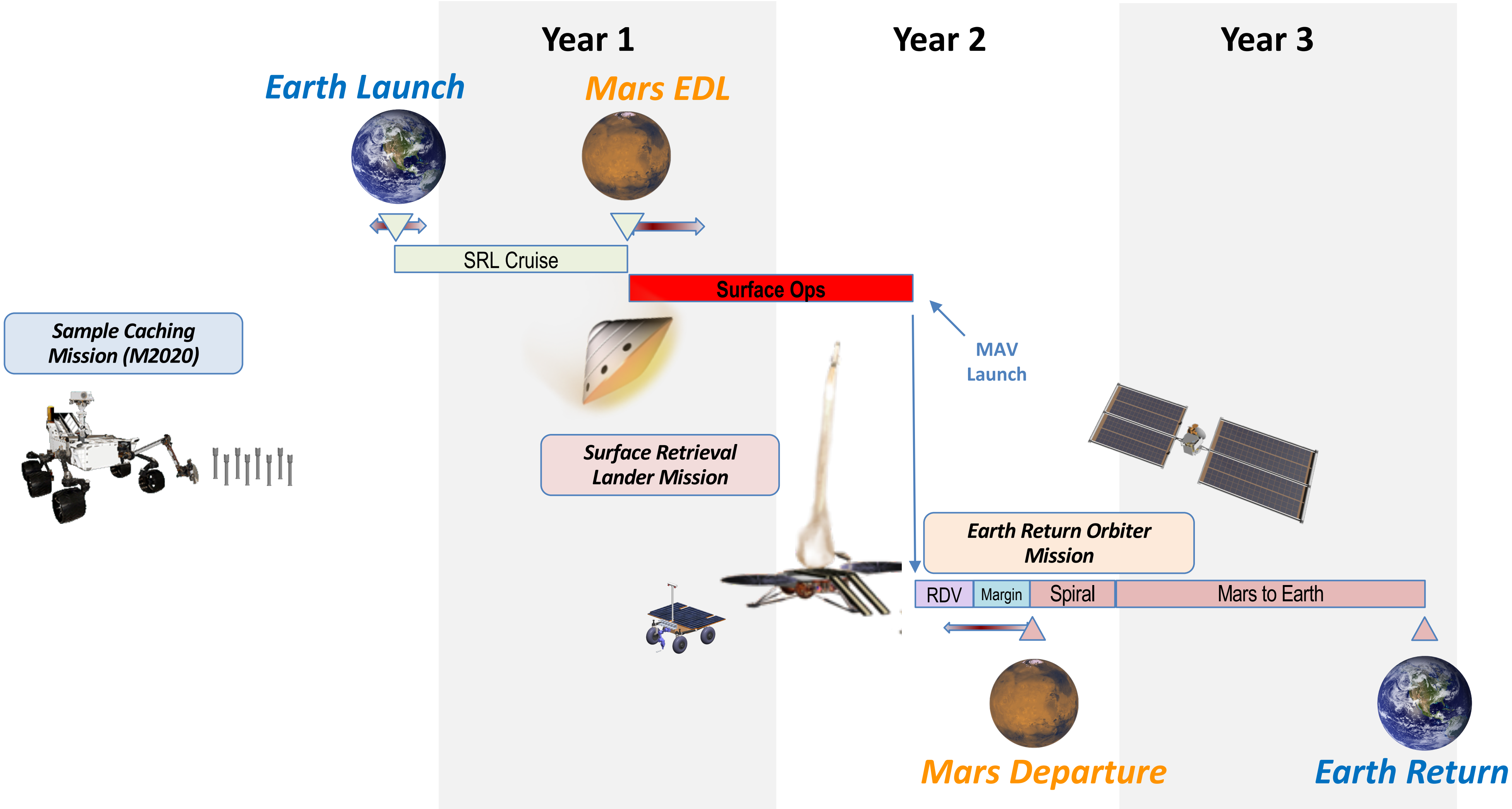


Summary

- The return to Earth of a scientifically selected set of diverse Martian samples is the next logical step in advancing our understanding of the Red Planet
- The most recent Planetary Decadal Survey has endorsed an MSR campaign architecture encompassing three missions:
  - Caching Rover
  - Sample Retrieval Lander
  - Earth Return Orbiter
- Mars 2020 is in development and provides the caching rover functionality
- NASA and ESA are now studying the potential SRL and ERO follow-on missions
- Key technology developments for the follow-on missions are underway
- Joint NASA/ESA study results will be available by end of CY 2019, in time to inform the next ESA Ministerial Council meeting

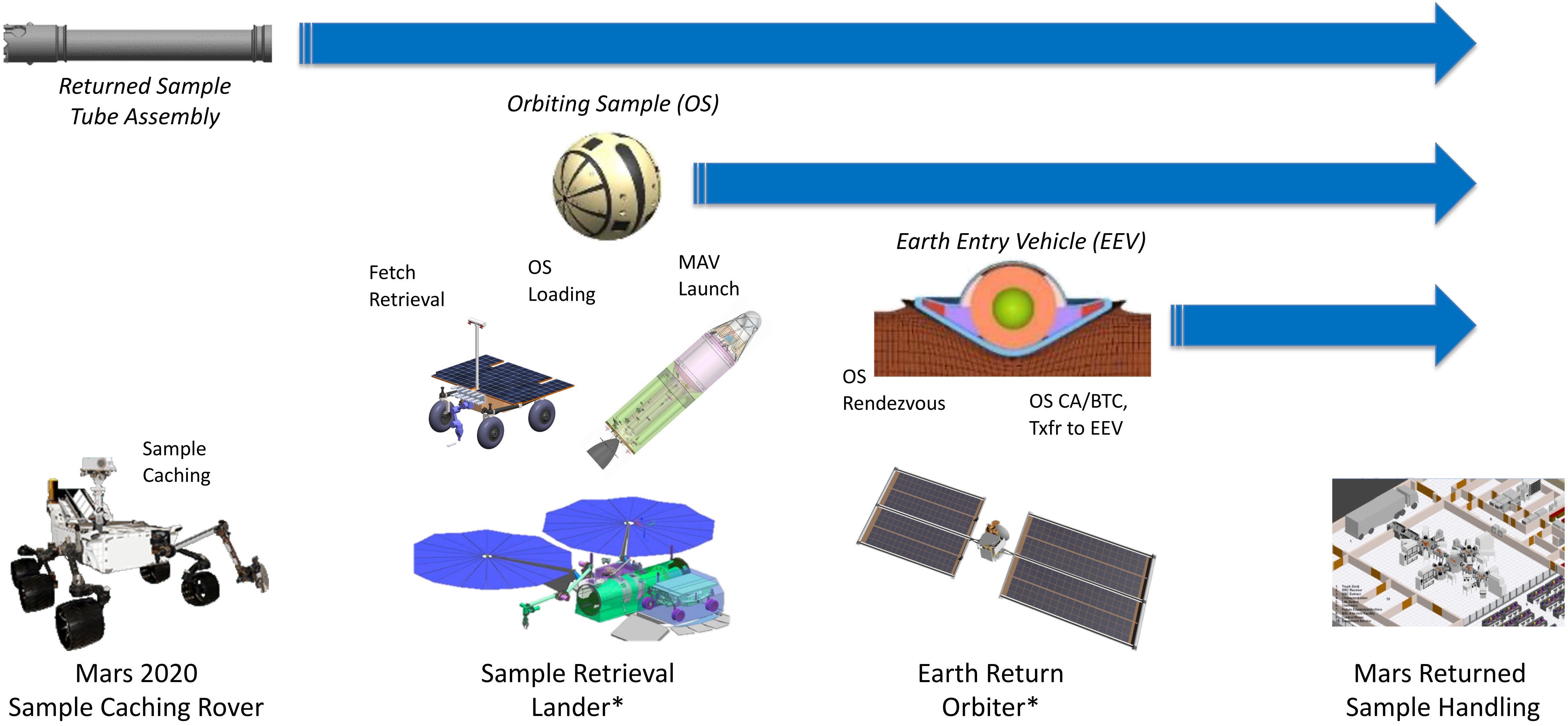
Backup

Notional "Fast" MSR Timeline



Fast timeline could return samples to Earth ~3 yrs after SRL launch

Key MSR Cross-Element Interfaces



*Concepts

Key Campaign-level Technical Trades

M2020 Sample Caching Strategy
- Depot(s)
- Add'l M2020 Extended Mission Caching?
- M2020 Sample Tube Delivery?

SRL/ERO Joint Mission Timelines
- SRL/ERO Launch Dates
  - ERO chem vs. SEP propulsion
- SRL Surface Mission Timeline
- ERO Orbital RDV timeline
- ERO Relay Support to SRL?
- Earth return date

MAV
- Targeted Orbit (Altitude, Inclination)
- Delivered Orbit Accuracy

OS
- Mass/Volume
- RF Beacon?
- Atmospheric Samples?

Containment Assurance
- BTC on surface and/or in orbit
- CA method(s)

Earth Return Strategy
- Direct Earth Return
- Cis-Lunar Delivery w/ Crewed Return